

IOP Conference Series: Materials Science and Engineering

PAPER • **OPEN ACCESS**

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To cite this article: E Tarigan 2017 *IOP Conf. Ser.: Mater. Sci. Eng.* **273** 012010

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Performance test of a grid-tied PV system to power a split air conditioner system in Surabaya

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Abstract. Air conditioner for cooling air is one of the major needs for those who live in hot climate area such as Indonesia. This work presents the performance test of a grid-tied PV system to power air conditioner under a hot tropical climate in Surabaya, Indonesia. A 800 WP grid-tied photovoltaic (PV) system was used, and its performance was tested to power a 0.5 pk of split air conditioner system. It was found that about 3.5 kWh daily energy was consumed by the tested air conditioner system, and about 80% it could be supplied from the PV system. While the other 20% was supplied by the grid during periods of low solar irradiation, 440 Wh of energy was fed into the grid during operation out of office hours. By using the grid-tied PV system, the energy production by PV system did not need to match the consumption of the air conditioner. However, a larger capacity of PV system would mean that a higher percentage of the load would be covered by PV system.

1. Introduction

Solar energy is one of the most promising renewable energy resources that can be expected to reduce fossil fuels consumption, and in turn to reduce the emission of greenhouse gas in the atmosphere. New innovative solutions need to be attempted in both engineering and policy to promote the solar energy use. Air conditioner for cooling air is one of the major needs for those who live in hot climate area such as Indonesia; even air conditioning is commonly used during all year round. About 50%–60% of buildings energy are commonly from air conditioning needs [1].

For its location that is very close to the equator line, solar irradiation in Surabaya, Indonesia, is relatively high, ranging from 4.8–5.8 kWh/m².day [2]. The ambient temperature is also relatively high with an average of 32 °C and 30 °C during dry and wet season, respectively [3]. Therefore, cooling demands for a building is very high throughout the year. On the other hand, solar electricity should be a good option to supply energy for cooling. Surabaya is suitable location to perform the possibility of using air conditioners powered by photovoltaic. The result can be a reference or adopted to other countries or cities with similar weather.

There are several previous works on solar air conditioner have been reported. A study on the design and construction of air conditioning system integrated with a direct current (DC) generated from PV was reported by Daut et al. [4]. To achieve the space cooling, the system design should consider both PV system (such as electrical equivalent, IV characteristic curve and factors affect the output of PV cell) and air conditioner, especially cooling capacity. Tsoutsos et al. [5] reported the performance and economic evaluation of a solar heating and cooling system of a TRNSYS simulation program. It was



found that the exploitation of the results of the simulation provided the optimum sizing of the solar system. The studies provided a good guideline in a design process

Aguilar et al. [6] reported a study of employing PV panels to supply electricity to power the compressor of the inverter for an air conditioner unit without batteries or any regulator. Here the inverter of the air conditioner was connected to both PV panels and grid. One advantage of using an inverter air conditioner was that it uses. The advantage of such system is the using of the direct current directly from the photovoltaic without inverter, that means reducing cost and increasing the efficiency energy conversion.

The peak time of using air conditioner for an office is commonly during the day when the hot weather (high solar radiation) and temperature is high, on the other hand at the same time PV panels produces electricity at optimum. In the present work, a grid-tied PV system was tested for its performance to power a split air conditioner under a hot tropical climate in Surabaya, Indonesia. The solar fraction and the advantages and limitation of such system were discussed.

2. Methods

The tested air conditioner unit was a split type with a capacity of 0.5 pk manufactured by Daikin®. The unit pk (stands for paardkracht, Dutch words) was the common commercial unit for air conditioner unit power in Indonesia, where 1 pk = 745.7 Watt. Therefore, the tested air conditioner system in the present work was about 372.85 Watt. The system was used for cooling a small office room with a floor area of 9 m².

Grid-tied PV system components consist of: 800 Wp monocrystalline silicon (4 modules of @200 Wp) connected with a 1000 Watt of the grid-tied inverter. The specification of the grid-tied inverter used is as presented in Table 1.

Table 1. Specification of grid-tied inverter.

Specifications	Unit/Explanation
Output Power	1000 W
Inverter Type	DC to AC
Output wave	Pure Sine
Input Voltage	20 – 48 Volt DC
Output Voltage	230Volt AC (with range of 190-260 Volt AC)
Output Frequency	Automatic detection of 45-53Hz / 55Hz-63Hz
Max. Current (DC)	50A
MPPT voltage	26-36VDC
Power Factor	>97%
System type	Grid tie
Max. Input power solar panel	1200 W

The parameters measured for analysis were:

- the DC power from PV modules,
- the AC output power from the inverter,
- solar radiation,
- inside and outside temperatures,
- power consumption air conditioner,
- The start-up power of the air conditioner.

The measurement devices and experiment setup are schematically shown in Figure 1. In the figure, EM1, EM2, and EM3, refers the measurement equipment for energy meter which continuously recording energy in kWh unit. A data logger was used to record the parameters for temperatures, solar radiation, current (A) and voltage (V).

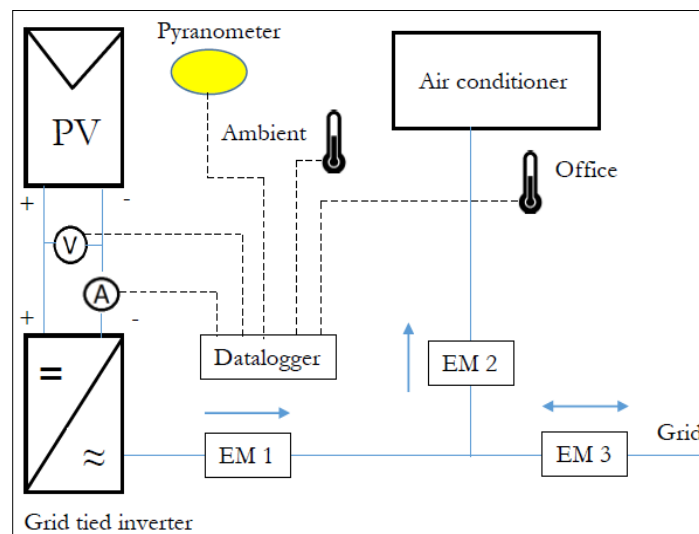


Figure 1. Experiment and measurement devices schematically.

3. Results and discussion

The air conditioner system was set on the temperature of 22 °C and ran during 07:30 to 17:30 fitting with typical office hours period and condition of a typical office in Indonesia. The power consumption of the air during the office hours was approximately 350W and total energy demand is about 3.45 kWh/day. The power rate of air conditioner system over time is shown in Figure 2.

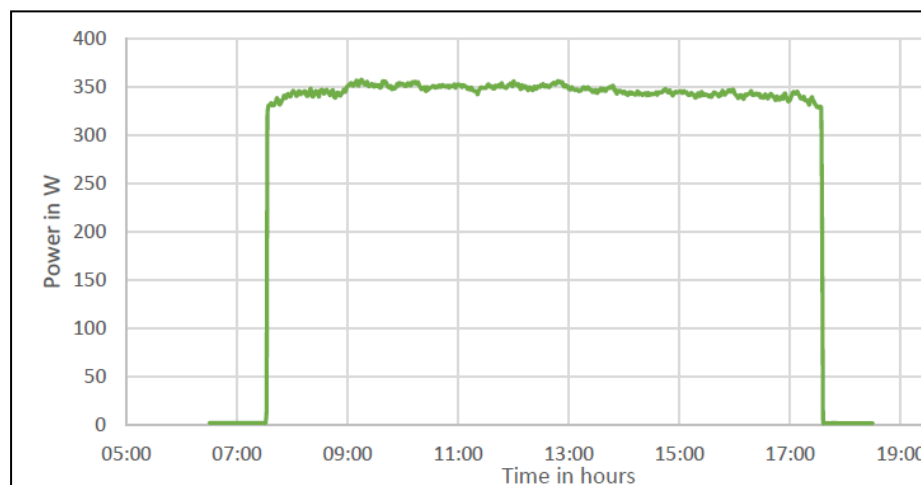


Figure 2. Power consumed by 0.5 pk air conditioner.

The amount of electricity energy produced by the PV system depends on irradiation values. The periods of high energy production are the times of high solar irradiation. The experiments were conducted during first week of May 2016. The weather was relatively clear sky with average daily radiation of 5.1 kWh/m².

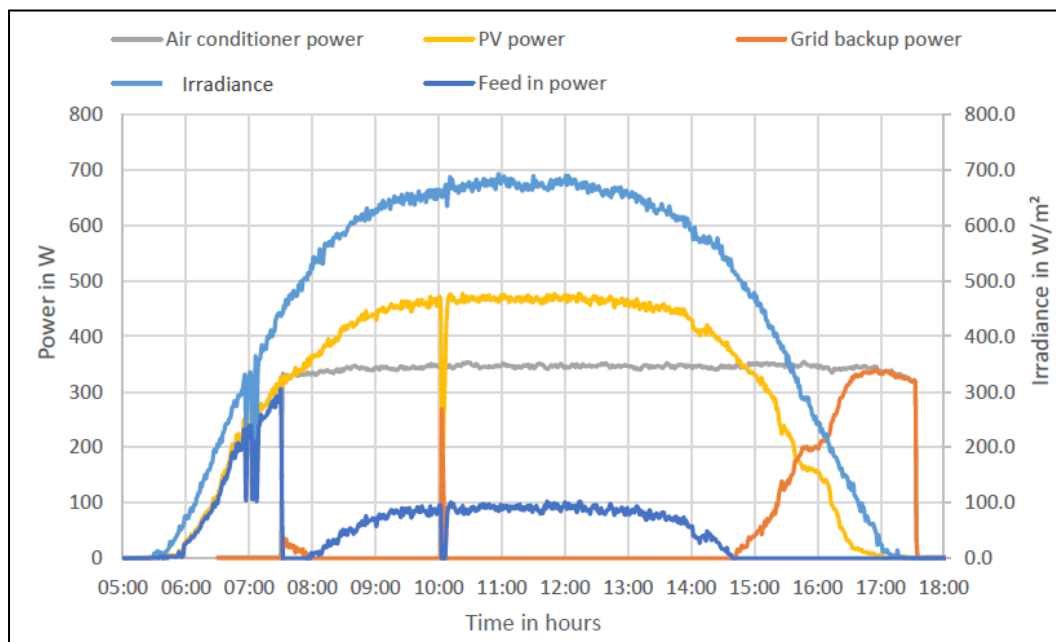


Figure 3. Diurnal variation of AC power, PV power, Backup power, Irradiance and Feed in power.

Figure 3 shows the typical one day measurement results for a sunny day. The figure shows the diurnal variation of the power consumed by the air conditioner, power from PV systems, backup power by the grid, solar irradiance and the feed-in power. It displays how the air conditioning, PV system, and the sun work together. It can be interpreted that during 05:30–07:30 when the air conditioner system was still off, the energy produced by PV was fed into the grid. When the air conditioner was switched on at 07:30 the energy production by PV was still too low to fully run the air conditioner. Therefore some portion of power was supplied by the grid. A significant high of power was also needed from the grid for the air conditioner start-up. However, it could not be seen in the graph as it happened in very short of periods (less than a second). From 08:00 irradiance and PV production continued to rise, and the power produced reached 450 W. While air conditioner power consumption was at the level of 350 W means that 100 W excess energy was exported into the grid. This condition was continuously happening until about 14:00. From 14:00–14:40 solar radiation was decreasing and power produced by PV was getting lower, resulting in decreasing of feed in power. From 14:40 the PV system obviously could no longer fully power the air conditioner, and then the backup power from the grid slowly increased until 17:00 when it was fully powered by the grid, and at 17:30 it switched off.

From results for four consecutive days of experiments as presented in Table 2, it was found that about 3.45 kWh was needed daily by the air conditioner system for running during office hour, and 80% of it (about 2.7 kWh) was supplied by PV panels as called solar fraction. The energy produced by PV system during period of before and after office hour was about 440 Wh. That means that PV panel almost supply all of energy needed by the air conditioner systems.

In such grid-tied PV system, the backup from the grid has two major functions. First, it is to supply power when low PV energy production due to low solar irradiation. In our case, the backup power from the grid was 20% and the majority of use during the last two hours of the office hours. To decrease of power from the grid, it could be attempted by adding more PV panels. However, it would have to be oversized, and it should be considered that from 15:00 onwards the solar irradiation is below 300 W/m². To fully power of the air conditioner with PV system during this period was not possible unless using of batteries to store excess power. However, this was an expensive solution. The

second function of the backup power from the grid was to power the air conditioner during start-up. This means to eliminate the need to oversize the inverter which is related to the cost and efficiency.

Table 2. Experiment results for four consecutive days for period of 7.30–17.30.

Day	Average power (W)	Energy demand (kWh)	Inverter output use by AC (kWh)	Solar fraction (%)
1	345	3.47	2.76	79.4
2	342	3.44	2.70	78.3
3	343	3.45	2.82	81.7
4	344	3.46	2.65	76.6

When the grid is available, a grid-tied PV system is considerably the best solution for a PV powered air conditioning. The advantages of the system are its simple system means less complexity of the PV system; low cost as it does not need batteries and charge controller; reliable; no need oversized inverter; the possibility of exporting excess electricity; and adaptable. The government of Indonesia is introducing a feed-in tariff policy for renewable energy resources [7]. If this is applied, a grid-tied system would be more attractive. The limitations of grid-tied system are, it is not 100% powered by PV system, weather dependent, and it is not functioned during blackouts.

4. Conclusion

A 800 WP grid-tied photovoltaic (PV) system has been tested to power a 0.5 pk of split air conditioner system. About 3.5 kWh daily energy was consumed by the air conditioner system, and about 80% of it could be supplied from the PV system, while the other 20% was supplied by the grid during periods of low solar irradiation, and 440 Wh of energy was fed to the grid during out of office hours operation. A grid-tied PV system is considerably the best solution for a PV powered air conditioning where the grid is available. The advantages grid-tied system are the simplicity of the system; low cost in comparison with off grid system; reliable; no need for oversized inverter; the possibility of exporting excess electricity; and adaptable.

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